JAPANESE PATENT PUBLICATION (A)

(11)Publication number : 08-123495

(43)Date of publication of application : 17.05.1996

(51)Int.CI. G10L 9/14
G10L 9/18
H04B 14/04

(21)Application number : 06-265277

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(22)Date of filing : 28.10.1994

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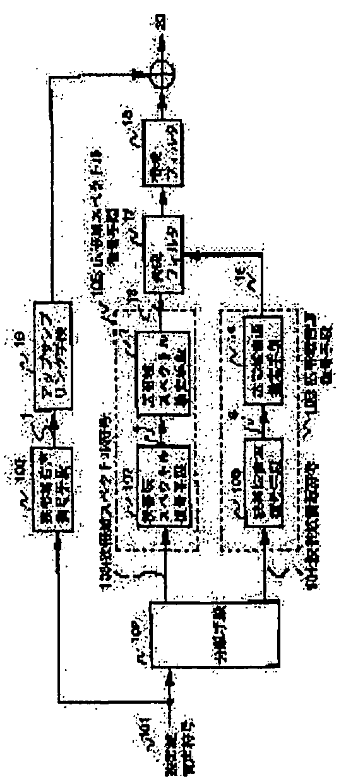
(54) **WIDE-BAND SPEECH RECOVERY DEVICE**



(57)Abstract:
PURPOSE: To provide a wide-band speech recovery device which estimates a stable wide-band source with a more accurate amplitude from narrow-band speech or a narrow-band speech code without being affected too much by a difference in speakers or noise and recovers a wide-band speech signal of a high quality.
CONSTITUTION: This device is provided with a narrow-band source decoding means which uses a narrow-band speech code to generate narrow-band synthesized

sound, a spectrum decoding means which uses a narrow-band spectrum code separated from the narrow-band speech code to estimate a wide-band spectrum parameter, a wide-band source decoding means which uses a narrow-band source code separated from the narrow-band speech code to estimate a wide-band source signal, and a synthesizing means which generates a wide-band speech signal from the generated narrow-band synthesized sound, the estimated wide-band spectrum parameter, and the wide-band source signal.

[CLAIMS]

[Claim 1] A wide-band speech recovery device provided with:
an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter and a narrow-band source signal,
a spectrum estimating means for using said narrow-band spectrum parameter to estimate a wide-band spectrum parameter,
a wide-band source estimating means for using said narrow-band source signal to estimate a wide-band source signal, and
a synthesizing means for generating a wide-band speech signal from the estimated wide-band spectrum parameter and wide-band source signal.

[Claim 2] A wide-band speech recovery device according to claim 1, characterized by using as a wide-band source estimating means a zero-stuffing means for inserting a predetermined zero values into each sample interval of the narrow-band source signal of the input.

[Claim 3] A wide-band speech recovery device according to claim 1, characterized in that the wide-band source estimating means is comprised of:
a source analysis means for analyzing the narrow-band source signal of input to obtain a narrow-band adaptive source code and a narrow-band excitation source signal,

an adaptive source estimating means for using said narrow-band adaptive source code to estimate a wide-band adaptive source signal,
an excitation source estimating means for using said narrow-band excitation source signal to estimate a wide-band excitation source signal, and
an adding means for generating a wide-band source signal from the estimated wide-band adaptive source signal and wide-band excitation source signal.
[Claim 4] A wide-band speech recovery device according to claim 1, characterized in that the wide-band source estimating means is comprised of:
a source analysis means for analyzing the narrow-band source signal of input to obtain a narrow-band long-period predictive code and a narrow-band long-period predictive residual signal,
a long-period predictive residual estimating means for using said narrow-band long-period predictive residual signal to estimate a wide-band long-period predictive residual signal,
a wide-band long-period predictive code estimating means for using said narrow-band long-period predictive code to estimate a wide-band long-period predictive code,
and
a long-period synthesizing means for synthesizing a wide-band source signal from said estimated wide-band long-period predictive residual signal and wide-band long-period predictive code.
[Claim 5] A wide-band speech recovery device provided with an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter and narrow-band amplitude information,
a spectrum-estimating means for using said narrow-band spectrum parameter and said narrow-band amplitude information to estimate at least a wide-band spectrum

parameter or wide-band amplitude information, and
a synthesizing means for generating a wide-band speech signal from said estimated wide-band spectrum parameter and said wide-band amplitude information or a wide-band source signal.

[Claim 6] A wide-band speech recovery device provided with:
a wide-band estimating means for using a narrow-band speech signal to estimate a wide-band speech signal and
a post-filtering means for post-filtering the estimated wide-band speech signal.

[Claim 7] A wide-band speech recovery device provided with:
an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter,
a spectrum estimating means for using said narrow-band spectrum parameter as a wide-band spectrum parameter as it is to output a wide-band spectrum parameter, and
a synthesizing means for generating a wide-band speech signal from said output wide-band spectrum parameter.

[Claim 8] A wide-band speech recovery device provided with:
an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter,
a spectrum estimating means for converting said narrow-band spectrum parameter into another domain if needed, modifying it, inversely converting it to the domain of the spectrum parameter, and outputting a wide-band spectrum parameter, and
a synthesizing means for generating a wide-band speech signal from said output wide-band spectrum parameter.

[Claim 9] A wide-band speech recovery device provided with:
a spectrum decoding means for estimating a wide-band spectrum parameter from a narrow-band speech code and
a synthesizing means for generating a wide-band speech signal from this estimated wide-band spectrum parameter.

[Claim 10] A wide-band speech recovery device provided with:

a spectrum decoding means for using a narrow-band spectrum code separated from a narrow-band speech code to estimate a wide-band spectrum parameter,
a wide-band source decoding means for using the narrow-band source code separated from said narrow-band speech code to estimate a wide-band source signal, and
a synthesizing means for generating a wide-band speech signal from the estimated wide-band spectrum parameter and wide-band source signal.

[Claim 11] A wide-band speech recovery device according to claim 10, characterized by using as a wide-band source decoding means a zero-stuffing means for inserting predetermined zero values into each sample interval of the narrow-band source signal recovered from the narrow-band source code.

[Claim 12] A wide-band speech recovery device according to claim 10, characterized in that the wide-band source decoding means is comprised of:
a wide-band adaptive source decoding means for using the narrow-band adaptive source code separated from the narrow-band speech code of input to estimate a wide-band adaptive source signal,
a wide-band excitation source decoding means for using the narrow-band excitation source code separated from the narrow-band speech code of input to estimate a wide-band excitation source signal, and
an adding means for generating a wide-band source signal from said estimated wide-band adaptive source signal and wide-band excitation source signal.

[Claim 13] A wide-band speech recovery device according to claim 10, characterized in that the wide-band source decoding means is comprised of:
a wide-band long-period predictive code decoding means for using the narrow-band long-period predictive code separated from the narrow-band speech code of input to estimate a

wide-band long-period predictive code,
a wide-band long-period predictive residual decoding means for using the narrow-band long-period predictive residual code separated from the narrow-band speech code of input to estimate a wide-band long-period predictive residual signal, and
an adding means for generating a wide-band source signal from said estimated wide-band long-period predictive code and wide-band long-period predictive residual signal.

[Claim 14] A wide-band speech recovery device provided with:
a narrow-band amplitude information decoding means for using the narrow-band source code separated from the narrow-band speech code to estimate narrow-band amplitude information,
a spectrum decoding means for using the narrow-band spectrum code separated from said narrow-band speech code and said narrow-band amplitude information to estimate at least a wide-band spectrum parameter or wide-band amplitude information, and
a synthesizing means for generating a wide-band speech signal from said wide-band spectrum parameter and if needed said estimated wide-band amplitude information or wide-band source signal.

[Claim 15] A wide-band speech recovery device provided with:
a wide-band speech decoding means for using a narrow-band speech code to estimate a wide-band speech signal and
a post-filtering means for post-filtering said decoded and estimated wide-band speech signal.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of Utilization in Industry] The present invention relates to a wide-band speech recovery device which recovers a wide-band speech signal from a band-limited

narrow-band speech signal or narrow-band speech code encoding a narrow-band speech signal.

[0002]

[Prior Art] As an example of a narrow-band speech signal, there is the current telephone speech. In a telephone system, the speech signal is transmitted restricted to the band from about 300 Hz to 3.4 kHz. Compared with when there is no band limitation, the speech consists of thin and muffled sounds. To improve the quality, it is possible to build a telephone system which can transmit a wide-band speech signal, but much time and expense would be required.

[0003] As a conventional method considered as a wide-band speech recovery method for recovering a wide-band speech signal from narrow-band speech restricted to the telephone band, there is Japanese Patent Publication (A) No. 6-118995.

[0004] Japanese Patent Publication (A) No. 6-118995 analyzes the narrow-band speech signal by LPC to calculate a spectrum parameter and uses this spectrum parameter as a narrow-band codebook for vector quantization. Further, it uses a wide-band codebook learned corresponding to the narrow-band codebook to decode a wide-band spectrum parameter. It uses this spectrum parameter for LPC synthesis to obtain a provisional wide-band speech signal. It up-samples the narrow-band speech signal and extracts and adds band components other than the narrow-band speech signal from the provisional wide-band speech signal so as to generate the final wide-band speech signal. Note that in wide-band LPC synthesis processing, a wide-band source signal is needed, but the method of generation of this source signal is not specifically disclosed.

[0005] As a reference which has the same configuration as Japanese Patent Publication (A) No. 6-118995 and in which the generation of the source signal is disclosed, there is Reference 1 "Recovery of wide-band speech from narrow-band

speech using codebook mapping", Institute of Electronics, Information and Communication Engineers, *Shingaku Giho* SP93-61 (1993-08).

[0006] Reference 1 discloses two methods as methods for wide-band source generation. The first method analyzes narrow-band speech and uses the obtained pitch and power to perform source generation by a method general in the business. That is, for voiced sound, it generates an impulse train repeating by the pitch period, while for unvoiced sound, it generates white noise and determines the amplitude by the power. Note that Reference 1 performs several post-processing to improve the sound quality. When recovering the low band of 300 Hz or less, it compensates for the lack of power of the recovered band by multiplying the power of the low-band recovered sound by a low multiple. When recovering the high band from 3.4 Hz to 7.3 kHz, it reduces the pulse-like sound generated using the impulse train as a source by applying a cosine function so as to flatten the pulses.

[0007] The second method vector-quantizes the spectrum parameter of a narrow-band speech signal and selects a representative waveform slice of the narrow-band and a representative waveform slice of the high band corresponding to the obtained code. It then performs the following processing on these two waveform slices. It judges voiced/unvoiced sounds of the waveform slices and, in the case of a voiced sound, overlays the waveform slice in synchronization with the pitch obtained by analysis of the narrow-band speech signal. In the case of an unvoiced sound, it cuts out a signal of the necessary length from a random location of the waveform slice. It then calculates the power ratio of the synthesized sound synthesized using the signal generated by said processing from the narrow-band waveform slice and the narrow-band spectrum parameter and the narrow-band speech. Further, it uses the signal

generated by said processing from the high-band waveform slice and the wide-band spectrum parameter to generate synthesized sound and multiplies this with the power ratio to obtain the high-band recovered signal.

[0008] Although the fields of the inventions differ, as another method for expanding the band of the source signal, there is the art disclosed in Reference 2 "A 2.4 Kbps High-Quality Speech Coder", *IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 1, S9.5, pp. 589-592 (1991.5).

[0009] Reference 2 relates to a system for high efficiency encoding and decoding of telephone band speech. It reduces the amount of information of the source at the time of encoding by long-period predictive analysis of the source signal from 0 Hz to 3.4 kHz and separation into a long-period predictive coefficient and a long-period predictive residual signal. It limits the band of the 0 Hz to 3.4 kHz long-period predictive residual signal to 0 Hz to 1 kHz for the encoding. Further, at the time of decoding, it generates a long-period predictive residual signal of the telephone band up to 3.4 kHz from the band-limited long-period predictive residual signal, then performs long-period synthesis processing to recover the source signal. The long-period predictive residual signal is recovered by up-sampling the signal having the 0 Hz to 1 kHz component to the sampling frequency of 8 kHz, then leaving it at four sample intervals and making the rest zero.

[0010]

[Problem(s) to be Solved by the Invention] The above conventional methods have the problems described below. Japanese Patent Publication (A) No. 6-118995 and, although a separate reference, Reference 1 disclosing specific examples of the same have roughly speaking the following four problems, that is, problems relating to estimation of the source amplitude, method of source generation, method

of estimation of spectrum parameter, and the communication system. First, the first estimation of the source amplitude will be explained. When using the first source generation method of Reference 1, for the power used for synthesis of the recovered sound, the power value obtained by analyzing the narrow-band speech is used as it is or the value obtained by multiplying this by a constant is used, but a narrow-band spectrum parameter and an estimated wide-band spectrum parameter differ in gain of the synthesis filter, so the amplitude of the synthesized sound obtained will differ even if giving the same source amplitude. Since this difference changes for every frame, there is the problem that wide-band speech with the correct amplitude is not recovered by just multiplying the source amplitude, i.e., the power value, by a constant. Moreover, when using the second source generation method of Reference 1, narrow-band synthesized sound is generated and the power ratio with the narrow-band speech is calculated and multiplied with the high-band synthesized sound, but there is the problem that complicated processing of two waveform slices becomes necessary.

[0011] Next, the second source generation method will be explained. When using the first source generation method of Reference 1, a wide-band source signal is generated just by the slight information of the pitch and power, so the diversely changing original wide-band source cannot be fully estimated. As a result, a cosine function is used to reduce the pulse-like sound, but the pulse-like sound cannot be completely suppressed and therefore there is the problem that the quality becomes unnatural. Moreover, it is impossible to express a voiced source, which differs greatly in properties for every speaker, by a single fixed source, so there is the problem that the quality deteriorates depending on the speaker. When using the second source generation method of Reference 1, a

representative waveform slice corresponding to the code of the result of vector quantization of a spectrum parameter is used, but originally speaking a spectrum parameter depends on the shape of the vocal tract and the source waveform depends on the oscillation of the vocal cords, so there is no strong correspondence between the two. The source waveform rather is largely dependent on the speaker. Therefore, there is the problem that a suitable source is not selected.

[0012] As described in Reference 1, when using the second sound source generation method, in spite of being a voiced sound, sometimes a waveform slice of unvoiced sound is selected or conversely in spite of being an unvoiced sound, sometimes a waveform slice of voiced sound is selected. If synthesizing sound in this state, there is the problem of degradation of quality. To avoid this, the power ratio at that part is compulsorily set to 0, but as a result the recovered high-band amplitude ends up partially becoming 0, so there is the problem of other degradation in quality. Furthermore, in each source generation method, there is the problem that degradation of quality is unavoidable when voiced/unvoiced judgment or pitch extraction error occurs. In particular, when applied to a narrow-band speech signal where noise is superimposed, there is the problem that judgment error and extraction error increase and large degradation occurs. Moreover, since there are only the two modes of a voiced sound and unvoiced sound, there is the problem that a source with properties in-between them cannot be sufficiently expressed and degradation of quality takes place at the boundary parts of voiced sound and unvoiced sound.

[0013] Next, the third method of estimation of the spectrum parameter will be explained. Japanese Patent Publication (A) No. 6-118995 and Reference 1 perform vector quantization and inverse quantization using two codebooks,

but have the problems that a memory for storing the codebooks is required and that a large amount of processing is required for the quantization. Moreover, noise, unvoiced sound, and voiced sound can be easily differentiated by the power and the correspondence between the narrow-band spectrum parameter and the wide-band spectrum parameter changes by this differentiation. However, in any case, since the spectrum parameter and power are treated independently, the information about the power is not reflected in the estimation of the wide-band spectrum parameter. For this reason, if the shape of the narrow-band spectrum is similar, there is the problem that regardless of the size of the power, the same wide-band spectrum will be estimated.

[0014] Finally, the fourth application to a communication system will be explained. When applying the method of Japanese Patent Publication (A) No. 6-118995 and Reference 1 to a communication system, this comprises decoding the narrow-band synthesized sound from the received speech code, then reanalyzing this narrow-band synthesized sound and recovering the wide-band speech signal, but when a spectrum parameter and source information are separated, encoded, and transmitted, it may be efficient to directly use the speech code to recover the wide-band speech signal. That is, the method of Japanese Patent Publication (A) No. 6-118995 and Reference 1 have the problem of inefficiency in the point that reanalysis is required. Moreover, the parameter obtained by synthesis and reanalysis includes superimposed distortion due to interpolation at the time of synthesis, framing at the time of analysis, etc. The wide-band speech also deteriorates in quality.

[0015] Note that in Japanese Patent Publication (A) No. 6-118995 and Reference 1, no signal processing generally introduced for reduction of the noise feeling of synthesized sound or improvement of intelligibility is

added, so when the quality of the recovered wide-band speech signal is insufficient, there is the problem that no improvement is possible. Moreover, when applied to a communication system, sometimes the narrow-band synthesized sound is signal processed. The processed narrow-band speech signal and the unprocessed wide-band speech signal are superimposed, so there is the problem that the continuity of the qualities of the two worsens.

[0016] With the method of Reference 2, if considering 0 Hz to 1 kHz as the narrow-band and 0 Hz to 3.4 kHz as the wide-band, this estimates a wide-band source signal, but as explained above, this system receives as input a wide-band speech signal, analyzes, encodes the obtained parameter, and decodes this to obtain a wide-band synthesized sound. It does not disclose a method of recovering a wide-band speech signal from a narrow-band speech signal or a parameter extracted from a narrow-band speech signal.

[0017] The present invention was made in order to solve these problems and has as its object to realize a wide-band speech recovery device which recovers a wide-band speech signal having a more correct amplitude from narrow-band speech. Moreover, it has as its object to realize a wide-band speech recovery device having processing for estimating the wide-band source amplitude by comparatively easy processing. Furthermore, it has as its object to realize a wide-band speech recovery device which has little reliance on the speaker, estimates a good wide-band source even near the voiced/unvoiced boundary, and recovers stable, natural quality wide-band speech. Moreover, it has as its object to realize the wide-band speech recovery device with little effect of voiced/unvoiced judgment error or pitch extraction error which tend to occur for a narrow-band speech signal on which noise is superimposed. Furthermore, it has as its object to realize a wide-band speech recovery device which recovers wide-band speech

efficiently without reanalysis when applied to a communication system. Furthermore, it has as its object to realize a wide-band speech recovery device which enables improvement when the quality of the recovered wide-band speech signal is insufficient and gives a wide-band speech signal with a good processed narrow-band continuity when signal processing is applied to a narrow-band synthesized sound.

[0018]

[Means for Solving the Problem] The wide-band speech recovery device according to the present invention is provided with an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter and a narrow-band source signal, a spectrum estimating means for using said narrow-band spectrum parameter to estimate a wide-band spectrum parameter, a wide-band source estimating means for using said narrow-band source signal to estimate a wide-band source signal, and a synthesizing means for generating a wide-band speech signal from the estimated wide-band spectrum parameter and wide-band source signal.

[0019] Further, it uses as a wide-band source estimating means a zero-stuffing means for inserting predetermined zero values into each sample interval of the narrow-band source signal of the input.

[0020] Further, the wide-band source estimating means is comprised of a source analysis means for analyzing the narrow-band source signal of input to obtain a narrow-band adaptive source code and a narrow-band excitation source signal, an adaptive source estimating means for using said narrow-band adaptive source code to estimate a wide-band adaptive source signal, an excitation source estimating means for using said narrow-band excitation source signal to estimate a wide-band excitation source signal, and an adding means for generating a wide-band source signal from

the estimated wide-band adaptive source signal and wide-band excitation source signal.

[0021] Further, the wide-band source estimating means is comprised of a source analysis means for analyzing the narrow-band source signal of input to obtain a narrow-band long-period predictive code and a narrow-band long-period predictive residual signal, a long-period predictive residual estimating means for using said narrow-band long-period predictive residual signal to estimate a wide-band long-period predictive residual signal, a wide-band long-period predictive code estimating means for using said narrow-band long-period predictive code to estimate a wide-band long-period predictive code, and a long-period synthesizing means for synthesizing a wide-band source signal from said estimated wide-band long-period predictive residual signal and wide-band long-period predictive code.

[0022] Another wide-band speech recovery device of the present invention is provided with an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter and narrow-band amplitude information, a spectrum-estimating means for using said narrow-band spectrum parameter and said narrow-band amplitude information to estimate at least a wide-band spectrum parameter or wide-band amplitude information, and a synthesizing means for generating a wide-band speech signal from said estimated wide-band spectrum parameter and said wide-band amplitude information or a wide-band source signal.

[0023] Further, it is provided with a wide-band estimating means for using a narrow-band speech signal to estimate a wide-band speech signal and
a post-filtering means for post-filtering the estimated wide-band speech signal.

[0024] Further, it is provided with an analysis means for analyzing a narrow-band speech signal to obtain a narrow-

band spectrum parameter, a spectrum estimating means for using said narrow-band spectrum parameter as a wide-band spectrum parameter as it is to output a wide-band spectrum parameter, and a synthesizing means for generating a wide-band speech signal from said output wide-band spectrum parameter.

[0025] Further, it is provided with an analysis means for analyzing a narrow-band speech signal to obtain a narrow-band spectrum parameter, a spectrum estimating means for converting said narrow-band spectrum parameter into another domain if needed, modifying it, inversely converting it to the domain of the spectrum parameter, and outputting a wide-band spectrum parameter, and a synthesizing means for generating a wide-band speech signal from said output wide-band spectrum parameter.

[0026] Another wide-band speech recovery device of the present invention is provided with a spectrum decoding means for estimating a wide-band spectrum parameter from a narrow-band speech code and a synthesizing means for generating a wide-band speech signal from this estimated wide-band spectrum parameter.

[0027] Further, it is provided with a spectrum decoding means for using a narrow-band spectrum code separated from a narrow-band speech code to estimate a wide-band spectrum parameter, a wide-band source decoding means for using the narrow-band source code separated from said narrow-band speech code to estimate a wide-band source signal, and a synthesizing means for generating a wide-band speech signal from the estimated wide-band spectrum parameter and wide-band source signal.

[0028] Further, it uses as a wide-band source decoding means a zero-stuffing means for inserting predetermined zero values into each sample interval of the narrow-band source signal recovered from the narrow-band source code.

[0029] Further, the wide-band source decoding means is

comprised of a wide-band adaptive source decoding means for using the narrow-band adaptive source code separated from the narrow-band speech code of input to estimate a wide-band adaptive source signal, a wide-band excitation source decoding means for using the narrow-band excitation source code separated from the narrow-band speech code of input to estimate a wide-band excitation source signal, and an adding means for generating a wide-band source signal from said estimated wide-band adaptive source signal and wide-band excitation source signal.

[0030] Further, the wide-band source decoding means is comprised of a wide-band long-period predictive code decoding means for using the narrow-band long-period predictive code separated from the narrow-band speech code of input to estimate a wide-band long-period predictive code, a wide-band long-period predictive residual decoding means for using the narrow-band long-period predictive residual code separated from the narrow-band speech code of input to estimate a wide-band long-period predictive residual signal, and an adding means for generating a wide-band source signal from said estimated wide-band long-period predictive code and wide-band long-period predictive residual signal.

[0031] Further, it is provided with a narrow-band amplitude information decoding means for using the narrow-band source code separated from the narrow-band speech code to estimate narrow-band amplitude information, a spectrum decoding means for using the narrow-band spectrum code separated from said narrow-band speech code and said narrow-band amplitude information to estimate at least a wide-band spectrum parameter or wide-band amplitude information, and a synthesizing means for generating a wide-band speech signal from said wide-band spectrum parameter and if needed said estimated wide-band amplitude information or wide-band source signal.

[0032] Further, it is provided with a wide-band speech decoding means for using a narrow-band speech code to estimate a wide-band speech signal and
a post-filtering means for post-filtering said decoded and estimated wide-band speech signal.

[0033]

[Mode of Operation] The wide-band speech recovery device in the present invention uses the wide-band spectrum parameter estimated using the narrow-band spectrum parameter and the wide-band source signal estimated using the narrow-band source signal to synthesize the wide-band speech signal.

[0034] Moreover, predetermined numbers of zeros are inserted between samples of the narrow-band source signal to generate the wide-band source signal and this and the estimated wide-band spectrum are used to synthesize the wide-band speech signal.

[0035] Moreover, in estimation of the wide-band source signal, the device analyzes the narrow-band source signal of the input to calculate the narrow-band adaptive source code and the narrow-band excitation source signal and adds the wide-band adaptive source signal estimated using the narrow-band adaptive source code and the wide-band excitation source signal estimated using the narrow-band excitation source to obtain the wide-band source signal. It then uses this and the estimated wide-band spectrum to synthesize the wide-band speech signal.

[0036] Moreover, as another method of estimation of the wide-band source signal, the device analyzes the narrow-band source signal of the input to calculate the narrow-band long-period predictive code and the narrow-band long-period residual signal and uses the wide-band long-period predictive code estimated using the narrow-band long-period predictive code and the wide-band long-period residual signal estimated using the narrow-band long-period residual signal to obtain the wide-band source signal. It then uses

this and the estimated wide-band spectrum to synthesize the wide-band speech signal.

[0037] Moreover, another wide-band speech recovery device in the present invention analyzes the narrow-band speech signal to calculate a narrow-band spectrum parameter, narrow-band amplitude information, and narrow-band source signal and uses the narrow-band spectrum parameter and narrow-band amplitude information to estimate one or both of the wide-band spectrum parameter and wide-band amplitude information. After this, it uses these signals and the wide-band source signal estimated from the narrow-band source signal to synthesize the wide-band speech signal.

[0038] Moreover, another wide-band speech recovery device in the present invention post-filters the wide-band speech signal estimated using the narrow-band speech signal to mainly process the high-band properties.

[0039] Moreover, another wide-band speech recovery device in the present invention extends the properties of the narrow-band spectrum parameter over the entire band and uses this parameter as the wide-band spectrum parameter to synthesize the wide-band speech signal.

[0040] Moreover, another wide-band speech recovery device in the present invention uses up to a specific degree of the narrow-band spectrum parameter and inversely converts this to the corresponding spectrum parameter to obtain the wide-band spectrum parameter, then uses this to synthesize the wide-band speech signal.

[0041] Moreover, another wide-band speech recovery device in the present invention uses the narrow-band speech code to generate the narrow-band synthesized sound and estimate the wide-band speech signal and adds to the signal obtained by up-sampling the narrow-band synthesized sound or the narrow-band synthesized sound a signal obtained by extracting mainly the high-band components other than the narrow-band synthesized sound from said wide-band speech

signal so as to synthesize the wide-band speech signal.

[0042] Moreover, another wide-band speech recovery device in the present invention uses the wide-band spectrum parameter estimated using the narrow-band spectrum code and the wide-band source signal estimated using the narrow-band source code to synthesize the wide-band speech signal.

[0043] Furthermore, the wide-band source decoding means inserts predetermined numbers of zero values between samples of the narrow-band source decoded using the narrow-band source code to generate a wide-band source signal and uses this and the estimated wide-band spectrum to synthesize the wide-band speech signal.

[0044] Moreover, another wide-band source decoding means in the present invention adds the wide-band adaptive source signal estimated using the narrow-band adaptive source code and the wide-band excitation sound signal estimated from the narrow-band excitation source signal to generate the wide-band source signal. It uses this and the estimated wide-band spectrum to synthesize the wide-band speech signal.

[0045] Moreover, another wide-band source decoding means in the present invention synthesizes the wide-band source signal from the wide-band long-period predictive code estimated using the narrow-band source code and the wide-band long-period residual signal estimated from the narrow-band long-period predictive residual signal. It uses this and the estimated wide-band spectrum to synthesize the wide-band speech signal.

[0046] Moreover, another wide-band speech recovery device in the present invention uses the narrow-band spectrum code and narrow-band amplitude information to estimate one or both of the wide-band spectrum parameter and wide-band amplitude information. After this, it synthesizes the wide-band speech signal from this information and the wide-band source signal estimated from the narrow-band source signal.

[0047] Moreover, another wide-band speech recovery device in the present invention post-filters the wide-band speech signal estimated using the narrow-band speech code to mainly process the high-band properties.

[0048]

[Examples]

Example 1. One example of the present invention will be explained based on the drawings. This example is one for explaining the configuration and operation for mainly recovering the generation of a wide-band source signal in a more correct form. FIG. 1 is a view of the configuration of the wide-band speech recovery device of Example 1 of the present invention. In the figure, 1 is a narrow-band speech signal of input, 2 is an analysis means, 3 is a spectrum analysis means, 4 is a narrow-band spectrum parameter, 5 is an inverse filter, 6 is a narrow-band source signal, 7 is a wide-band spectrum estimating means, 8 is a vector quantizing means, 9 is a narrow-band spectrum codebook, 10 is a spectrum code, 11 is an inverse quantizing means, 12 is a wide-band spectrum codebook, and 13 is a wide-band spectrum parameter. 14 is an important new component in this example, that is, a wide-band source estimating means, 15 is a zero-stuffing means as a specific example of this, 16 is a wide-band source signal, 17 is a synthesis filter as a synthesizing means, 18 is a band-pass filter, 19 is up-sampling means, and 20 is a wide-band speech signal. Moreover, FIG. 2 is a explanatory view of signals for explaining the processing of the zero-stuffing means 15.

[0049] Below, the operation of Example 1 of the present invention will be explained using FIG. 1 and FIG. 2. First, a narrow-band speech signal 1 sampled, for example, at 8 kHz and restricted to the 300 Hz to 3.4 kHz telephone band is input into the analysis means 2 and the up-sampling means 19. The spectrum analysis means 3 within the analysis means 2 analyzes the narrow-band speech signal 1 to

calculate the narrow-band spectrum parameter 4 and outputs it to the inverse filter 5 within the analysis means 2 and the wide-band spectrum estimating means 7. Note that as the narrow-band spectrum parameter 4, various parameters such as a linear prediction coefficient, LSP, PARCOR coefficient, or Cepstrum are applicable. The inverse filter 5 uses the narrow-band spectrum parameter 4 for inverse filtering of the narrow-band speech signal 1 and outputs the obtained narrow-band source signal 6 to the wide-band source estimating means 14.

[0050] The vector quantizing means 8 within the wide-band spectrum estimating means 7 uses the narrow-band spectrum codebook 9 to vector-quantize said narrow-band spectrum parameter 4 and outputs the obtained spectrum code 10 to the inverse quantizing means 11 within the wide-band spectrum estimating means 7. The inverse quantizing means 11 uses the wide-band spectrum codebook 12 to inversely quantize the spectrum code 10 and outputs the obtained wide-band spectrum parameter 13 to the synthesis filter 17. Note that the processing within this wide-band spectrum estimating means 7 is the same as that of Reference 1. A detailed explanation about the method of generating the narrow-band spectrum codebook 9 and the wide-band spectrum codebook 12 and the method of vector quantization is omitted.

[0051] The zero-stuffing means 15 within the wide-band source estimating means 14, which is an important part of this example, inserts M-1 samples of zero between sample values of the narrow-band source signal 6 and outputs the obtained M-fold number of samples of signals as the wide-band source signal 16 to the synthesis filter 17. Here, M is the sampling frequency of the wide-band speech signal for recovery divided by the sampling frequency of the narrow-band speech signal. In this example, the case where M is 2 will be explained. FIG. 2 (a) shows the narrow-band

source signal 6 of N samples. If zero stuffing the signal by the zero-stuffing means 15, M-1 samples, i.e., one for each sample, of zeros are inserted between samples whereby the 2-N samples of the wide-band source signal 16 shown in FIG. 2 (b) are obtained. If zero stuffing by M=2, a spectrum symmetrical to 0 Hz to 4kHz across the frequency of one half of the sampling frequency of the wide-band speech signal, is recovered from 4 kHz to 8 kHz.

[0052] The synthesis filter 17 uses the wide-band spectrum parameter 13 for synthesis filtering of the wide-band source signal 16 to generate a provisional wide-band speech signal. The band-pass filter 18 filters this provisional wide-band speech signal to extract components other than the band where the component of narrow-band speech exists. In the case where the band of the wide-band speech signal is from 0 Hz to 7.3 kHz, the components from 0 to 300 Hz and from 3.4 to 7.3 kHz are extracted. The up-sampling means 19 up-samples the narrow-band speech signal 1 M-fold. The signal generated by up-sampling is the same in sampling frequency as the wide-band speech signal 20 and has the same narrow-band component as the narrow-band speech signal 1. The output of the band-pass filter 18 and the output of the up-sampling means 19 are added to generate the wide-band speech signal 20.

[0053] Originally, the narrow-band source signal and the wide-band source signal reflect the features of the source signal generated from the same vocal organ and are correlated in the features of the source signal such as the strength of the harmonic components of the pitch frequency and the strength of the noise component between harmonic components. That is, when the narrow-band source signal has the regular feature of strong harmonic components of the pitch frequency, the wide-band source signal similarly has the regular feature of strong harmonic components of the pitch frequency. Conversely, when the narrow-band source

signal has the feature of strong noise-like components, the wide-band source signal similarly has the feature of strong noise-like components. By configuring the wide-band source estimating means like in this example, it is possible to generate a 0 to 8 kHz wide-band source signal having a feature similar to a low-band 0 to 4 kHz narrow-band source signal, so there are the effects that there is little dependence on the speaker and that stable, natural quality wide-band speech can be recovered. Moreover, since it is unnecessary to judge voiced/unvoiced and extract pitch like in the past examples and since a source of intermediate properties can also be expressed by this configuration, there are the effects that there is none of the effect of voiced/unvoiced judgment error or pitch extraction error which tend to occur in a narrow-band speech signal where noise is superimposed, a good wide-band source can be estimated even near a voiced/unvoiced boundary, and stable, natural quality wide-band speech can be recovered.

[0054] Example 2. FIG. 3 is a view of the configuration of the source estimating means 14 in the wide-band speech recovery device of Example 2 of the present invention. In the figure, the new parts are the source analysis means of 21, the narrow-band adaptive codebook of 22, the distortion minimizing means of 23, the narrow-band excitation source signal of 24, the narrow-band adaptive lag length of 25, the narrow-band adaptive gain of 26, the wide-band excitation source estimating means of 27, the zero-stuffing means of 28, the wide-band excitation source signal of 29, the wide-band adaptive source estimating means of 30, the wide-band adaptive source codebook of 31, the wide-band adaptive source signal of 32, the wide-band adaptive lag length of 33, and the wide-band adaptive gain of 34. The overall configuration is the same as FIG. 1, so a description of the configuration and explanations of the operation of parts other than in FIG. 3 are omitted.

According to this configuration, a wide-band source signal can be recovered even better.

[0055] Below, the operation of one example of the present invention will be explained using FIG. 3. A narrow-band source signal 6 is input into the source analysis means 21 within the wide-band source estimating means 14. The narrow-band adaptive codebook 22 within the source analysis means 21 stores past narrow-band source signals 6. When the lag length is a whole value, it outputs a signal obtained by repeating a stored past narrow-band source signal 6 by this lag length according to the lag length successively output by the later explained distortion minimizing means 23. When the lag length is not a whole value, as described in Reference 3 "Pitch Predictors with High Temporal Resolution," *IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 2, S12.6, pp. 661-664 (1990.4), it generates and outputs a signal by a polyphase filter output. The length of the signal which is output is the same length as the current narrow-band source signal 6.

[0056] FIG. 4 shows an example of a past narrow-band source signal 6 stored in the narrow-band adaptive codebook 22 and the signal output according to the input lag length. In the figure, the abscissa shows the time which elapses in the arrow direction. (A1) and (B1) therefore show length of time of the source signal, (A2) and (B2) show the lag length normalized to the time of output such as 20 to 128, and (A3) and (B3) show an example of the source signal output. FIG. 4(a) shows the case where the length of the output signal is shorter than lag length. In this case, a source signal (A3) of a length of the output signal time T1 is output after the past source signal from the beginning of lag length. When lag length is shorter than the length of the signal output such as T2, as shown in FIG. 4(b), the same source signal (B3) is repeatedly output following the past source signal a plurality of times.

[0057] The distortion minimizing means 23 sequentially outputs values of a plurality of lag lengths to said narrow-band adaptive codebook 22 and determines a gain to give the minimum the distortion between the signal obtained by multiplying the signal output by the narrow-band adaptive codebook 22 for each lag length with the gain and the narrow-band source signal 6. Further, it selects the lag length minimizing the distortion among all lag lengths and outputs it to the wide-band adaptive source estimating means 30 as the narrow-band adaptive lag length 25. Moreover, it outputs the value of the gain at that time as the narrow-band adaptive gain 26 to the wide-band adaptive source estimating means 30 and outputs the error signal between the signal obtained by multiplying the signal output by the narrow-band adaptive codebook 22 with the narrow-band adaptive gain 26 and the narrow-band source signal 6 as the narrow-band excitation source signal 24 to the wide-band excitation source estimating means 27. Note that as the method of determining the gain in the distortion minimizing means 23, the generally known Lagrange indeterminate coefficient method can be used. That is, the distortion minimizing means 23 receives as input the narrow-band source signal 6 and narrow-band adaptive codebook 22 output and outputs narrow-band adaptive source code, that is, the minimum distortion lag length 25 and gain 26, and the narrow-band excitation source signal 24 of the error signal.

[0058] The zero-stuffing means 28 within the wide-band excitation source estimating means 27 inserts M-1 samples of zeros between sample values of the narrow-band excitation source signal 24 and outputs the obtained M-fold number of samples of the signal as the wide-band excitation source signal 29. Here, M is the sampling frequency of the wide-band speech signal for recovery divided by the sampling frequency of the narrow-band speech signal. The

operation of insertion of zeros is the same as said zero-stuffing means 15.

[0059] The wide-band adaptive source estimating means 30 first multiplies the narrow-band adaptive lag length 25 by M to obtain the wide-band adaptive lag length 33 and multiplies the narrow-band adaptive gain 26 by g to obtain the wide-band adaptive gain 34. If g is made 1, the pitch periodicity of the wide-band source signal 16 finally obtained becomes equivalent to the narrow-band source signal 6. As this is made smaller from 1, the pitch periodicity becomes weaker compared with the narrow-band source signal 6. If observing actual speech, the higher the frequency of a part, often the weaker the pitch periodicity, so by setting g to a value smaller than 1 when recovering the high band, high quality wide-band speech can be recovered. The wide-band adaptive source codebook 31 within the wide-band adaptive source estimating means 30 stores the past wide-band source signals 16 and outputs a signal obtained by repeating these signals by the wide-band adaptive lag length 33. Further, the wide-band adaptive source estimating means 30 multiplies this signal with said wide-band adaptive gain 34 and outputs the result as the wide-band adaptive source signal 32. Finally, the device adds the wide-band excitation source signal 29 and the wide-band adaptive source signal 32 and outputs the result as the wide-band source signal 16.

[0060] By configuring the example in this way, the features relating to the strength and fluctuation of the pitch periodicity of the narrow-band source signal are expressed well by the narrow-band adaptive lag length 25 and the narrow-band adaptive gain 26 and reflected in the wide-band source signal, so a diversely changing source can fully be estimated, there is also no pulse-like sound, and good quality wide-band speech can be recovered. Further, there is the effect that a suitable source can be estimated

without regard as to the speaker. In the wide-band adaptive source signal 32, the basic frequency determined by the wide-band adaptive lag length 33 and the frequencies of its harmonic components are correctly arranged at whole multiple positions, so the relation of the narrow-band component and the recovered wide-band component in the wide-band speech signal 20 finally recovered is good, and high quality wide-band speech can be recovered. Furthermore, since the feature of the pitch periodicity becoming weaker as the frequency becomes higher can be introduced by the coefficient g, there is the effect that a natural quality can be obtained. Moreover, since voiced/unvoiced judgment and pitch extraction are not necessary and even a source of intermediate properties can be expressed, there are the effects that there is no effect of voiced/unvoiced judgment error or pitch extraction error which tend to occur in a narrow-band speech signal where noise is superimposed, a good wide-band source can be estimated even near the voiced/unvoiced boundary, and stable, natural quality wide-band speech can be recovered.

[0061] Example 3. FIG. 5 is a view of the configuration of the wide-band excitation source estimating means 27 in the wide-band speech recovery device of Example 3 of the present invention. In the figure, the new parts are the power calculating means of 35 and the noise generating means of 36. The rest of the configuration is the same as in FIG. 1 and FIG. 3, so explanations of operations of corresponding parts will be omitted.

[0062] Below, the operations of the parts shown in the drawing of Example 3 of the present invention will be explained using FIG. 5. The narrow-band excitation source signal 24 is input into the power calculating means 35 within the wide-band excitation source estimating means 27. The power calculating means 35 calculates and outputs the power of the narrow-band excitation source signal 24. The

noise generating means 36 generates and outputs a white-noise signal normalized in power. Further, the wide-band excitation source estimating means 27 multiplies said white-noise signal with the power which the power calculating means 35 outputs and outputs the obtained signal as the wide-band excitation source signal 29.

[0063] The pitch period or strength of periodicity changes every moment. Parts of fine fluctuation of the pitch period or strength of periodicity in the narrow-band source signal 6 cannot be expressed by the narrow-band adaptive lag length 25 and the narrow-band adaptive gain 26, so that error is included in the narrow-band excitation source signal 24. It has been confirmed by experiments that if using the narrow-band excitation source signal 24 which contains this error component to generate the wide-band excitation source signal 29 like in Example 2, the wide-band excitation source signal 29 will sometimes end up with unnecessary disturbances and that generating white noise with the same power and using it as the wide-band excitation source signal 29 gives a better recovered sound in some cases. By configuring the device like in Example 3, since white noise is generated with the same power as the narrow-band excitation source signal 24 and used as the wide-band excitation source signal 29, in addition to the effects of Example 2, there is the effect that a good recovered sound with little disturbances due to fluctuations of pitch period and strength of periodicity is obtained.

[0064] Moreover, if zero stuffing, symmetrical spectra are generated across 4 kHz. Therefore, if zero stuffing the narrow-band excitation source signal 24 with no components from 0 to 300 Hz and from 3.4 kHz to 4.0 kHz, a signal with no components from 0 Hz to 300 Hz, from 3.4 kHz to 4.6 kHz, and from 7.7 kHz to 8 kHz will end up being obtained. On the other hand, with this configuration using white noise,

the wide-band excitation source signal 29 which has all components from 0 Hz to 8 kHz is obtained, so there is the effect that a good recovered sound which has a band over the entire band is obtained. The effect is particularly large in recovery from 0 Hz to 300 Hz.

[0065] Example 4. FIG. 6 is a view of the configuration of the wide-band excitation source estimating means 27 in the wide-band speech recovery device of Example 4 of the present invention. In the figure, the zero-stuffing means of 28, the power calculating means of 35, and the noise generating means of 36 are the same as those of Example 2 and Example 3. The rest of the configuration is the same as in FIG. 1 and FIG. 3, so explanations of operation of parts other than those illustrated will be omitted.

[0066] Below, the operation of one example of the present invention will be explained using FIG. 6. The narrow-band excitation source signal 24 is input into the zero-stuffing means 28 and the power calculating means 35 within the wide-band excitation source estimating means 27. The zero-stuffing means 28 within the wide-band excitation source estimating means 27 inserts M-1 samples of zero between sample values of the narrow-band excitation source signal 24 and outputs the obtained M-fold number of samples of the signal. Here, M is the sampling frequency of the wide-band speech signal for recovery divided by the sampling frequency of a narrow-band speech signal. The operation for inserting the zeros is the same as said zero-stuffing means 15. The power calculating means 35 calculates and outputs the power of the narrow-band excitation source signal 24. The noise generating means 36 generates and outputs the white-noise signal normalized in power. Further, the means adds the signal obtained by multiplying the signal which the zero-stuffing means 28 output with the gain gr1 and the signal obtained by multiplying the white-noise signal which the noise generating means 36 outputs with the power which

the power calculating means 35 outputs and further multiplying this with the gain gr2 and outputs the result as the wide-band excitation source signal 29.

[0067] When the recovered sound of Example 2 and Example 3 has long and short parts, by configuring the device in this way and suitably setting gr1 and gr2, there is the effect that wide-band speech of a quality exceeding both may be recovered. Note that there are also the same effects as in Example 2 and Example 3.

[0068] Example 5. Another configuration enabling good recovery of a wide-band source signal will be explained. FIG. 7 is a view of the configuration of the wide-band source estimating means 14 in the wide-band speech recovery device of Example 5 of the present invention. In the figure, the new parts are the narrow-band long-period predictive analysis means of 37, the narrow-band long-period delay of 38, the narrow-band long-period prediction coefficient of 39, the long-period inverse filter of 40, the narrow-band long-period predictive residual signal of 41, the wide-band long-period predictive residual estimating means of 42, the zero-stuffing means of 43, the wide-band long-period prediction parameter (code) estimating means of 44, the wide-band long-period delay of 45, the wide-band long-period prediction coefficient of 46, the long-period synthesis filter of 47, and the wide-band long-period predictive residual signal of 48. The overall configuration is the same as in FIG. 1, so its explanation will be omitted.

[0069] Below, the operation of one example of the present invention will be explained using FIG. 7. The narrow-band source signal 6 is input into the source analysis means 21 within the wide-band source estimating means 14. The narrow-band long-period predictive analysis means 37 within the source analysis means 21 performs long-period predictive analysis on the narrow-band source signal 6 and

outputs narrow-band long-period predictive codes, that is, the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39. Note that long-period predictive analysis is a method often used in CELP coding methods, so its explanation will be omitted. The long-period inverse filter 40 within the source analysis means 21 uses the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39 for inverse filtering of the narrow-band source signal 6 and outputs the obtained signal as the narrow-band long-period predictive residual signal 41 to the wide-band long-period predictive residual estimating means 42.

[0070] The zero-stuffing means 43 within the wide-band long-period predictive residual estimating means 42 inserts M-1 samples of zero between sample values of the narrow-band long-period predictive residual signal 41 and outputs the M-fold number of samples of the signal as the wide-band long-period predictive residual signal 48. Here, M is the sampling frequency of the wide-band speech signal for recovery divided by the sampling frequency of the narrow-band speech signal. The operation for inserting zeros is the same as that of said zero-stuffing means 15.

[0071] The wide-band long-period prediction parameter (code) estimating means 44 multiplies the narrow-band long-period delay 38 by M to output one of the predictive codes, that is, the wide-band long-period delay 45, and multiplies the narrow-band long-period prediction coefficient 39 by g to output the other predictive code, that is, the wide-band long-period prediction coefficient 46. If setting g to 1, the pitch periodicity of the wide-band source signal 16 finally obtained becomes equivalent to the narrow-band source signal 6. As setting it smaller than 1, the pitch periodicity becomes weaker than the narrow-band source signal 6. In the same way as in Example 2, when recovering the high-band, setting g to a value smaller than 1 gives a

higher quality. Finally, the long-period synthesis filter 47 uses the wide-band long-period delay 45 and the wide-band long-period prediction coefficient 46 for long-period synthesis filtering of the wide-band long-period predictive residual signal 48 and outputs the obtained signal as the wide-band source signal 16.

[0072] By configuring the example in this way, the feature relating to the strength and fluctuation of the pitch periodicity of the narrow-band source signal is expressed well by the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39 and is reflected in the wide-band source signal, so there are the effects that a diversely changing source can be sufficiently estimated, there is also no pulse-like sound, and good quality wide-band speech can be recovered. Moreover, there is the effect that a suitable source can be estimated without regard as to the speaker. In the wide-band source signal 16, the basic frequency determined by the wide-band long-period delay 45 and the frequencies of the harmonic components are correctly arranged at whole multiple positions, so the relation of the narrow-band component and the recovered wide-band component in the wide-band speech signal 20 finally recovered is good, and high quality wide-band speech can be recovered. Furthermore, since the feature of the pitch periodicity becoming weaker as the frequency becomes higher can be introduced by the coefficient $\underline{g}$, there is the effect that a more natural quality can be obtained. Moreover, since voiced/unvoiced judgment and pitch extraction are not necessary and even a source of intermediate properties can be expressed, there are the effects that there is no effect of voiced/unvoiced judgment error or pitch extraction error which tend to occur in a narrow-band speech signal where noise is superimposed, a good wide-band source can be estimated even near the voiced/unvoiced boundary, and

stable, natural quality wide-band speech can be recovered.

[0073] Example 6. FIG. 8 is a view of the configuration of the wide-band long-period predictive residual estimating means 42 in the wide-band speech recovery device of Example 6 of the present invention. In the figure, the power calculating means of 35 and the noise generating means of 36 are the same as those of Example 3. The rest of the configuration is the same as in FIG. 1 and FIG. 7, so its explanation will be omitted.

[0074] Below, the operation of one example of the present invention will be explained using FIG. 8. The narrow-band long-period predictive residual signal 41 is input into the power calculating means 35 within the wide-band long-period predictive residual estimating means 42. The power calculating means 35 calculates and outputs the power of the narrow-band long-period predictive residual signal 41. The noise generating means 36 generates and outputs white-noise signal normalized in power. Further, the wide-band long-period predictive residual estimating means 42 multiplies said white-noise signal with the power which the power calculating means 35 outputs and outputs the obtained signal as the wide-band long-period predictive residual signal 48.

[0075] In the same way as the explanation in Example 3, parts of fine fluctuation of the pitch period or strength of periodicity in the narrow-band source signal 6 cannot be expressed by the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39, so that error is included in the narrow-band long-period predictive residual signal 41. If using the narrow-band long-period predictive residual signal 41 which contains this error component to generate the wide-band long-period predictive residual signal 48 like in Example 5, the wide-band long-period predictive residual signal 48 will sometimes end up with unnecessary disturbances and generating white noise

with the same power and using it as the wide-band long-period predictive residual signal 48 gives a better recovered sound in some cases. By configuring the device like in Example 6, since white noise is generated with the same power as the narrow-band long-period predictive residual signal 41and used as the wide-band long-period predictive residual signal 48, in addition to the effects of Example 5, there is the effect that a good recovered sound with little disturbances due to fluctuations of pitch period and strength of periodicity is obtained.

[0076] Moreover, if zero stuffing, symmetrical spectra are generated across 4 kHz. Therefore, if zero stuffing the narrow-band long-period predictive residual signal 41 with no components from 0 to 300 Hz and from 3.4 kHz to 4.0 kHz, a signal with no components from 0 Hz to 300 Hz, from 3.4 kHz to 4.6 kHz, and from 7.7 kHz to 8 kHz will end up being obtained. On the other hand, with this configuration using white noise, the wide-band long-period predictive residual signal 48 which has all components from 0 Hz to 8 kHz is obtained, so there is the effect that a good recovered sound which has no missing bands is obtained. The effect is particularly large in recovery from 0 Hz to 300 Hz.

[0077] Example 7. FIG. 9 is a view of the configuration of the wide-band long-period predictive residual estimating means 42 in the wide-band speech recovery device of Example 7 of the present invention. In the figure, the zero-stuffing means of 43, the power calculating means of 35, and the noise generating means of 36 are the same as those of Example 5 and Example 6. The rest of the configuration is the same as in FIG. 1 and FIG. 7, so its explanation will be omitted.

[0078] Below, the operation of one example of the present invention will be explained using FIG. 9. The narrow-band long-period predictive residual signal 41 is input into zero-stuffing means 43 and the power calculating means 35

within the wide-band long-period predictive residual estimating means 42. The zero-stuffing means 43 within the wide-band long-period predictive residual estimating means 42 inserts M-1 samples of zero between sample values of the narrow-band long-period predictive residual signal 41 and outputs M-fold the number of samples of the signal. Here, M is the sampling frequency of the wide-band speech signal for recovery divided by the sampling frequency of the narrow-band speech signal. The operation of inserting zeros is the same as said zero-stuffing means 15. The power calculating means 35 calculates and outputs the power of the narrow-band long-period predictive residual signal 41. The noise generating means 36 generates and outputs the white-noise signal normalized in power. Further, the means adds the signal obtained by multiplying the signal which the zero-stuffing means 43 outputs with the gain gr1 and the signal obtained by multiplying the white-noise signal which the noise generating means 36 outputs with the power which the power calculating means 35 outputs and further multiplying this with the gain gr2 and outputs the result as the wide-band long-period predictive residual signal 48.

[0079] When the recovered sound of Example 5 and Example 6 has long and short parts, by configuring the device in this way and suitably setting gr1 and gr2, there is the effect that wide-band speech of a quality exceeding both may be recovered. Note that there are also the same effects as in Example 5 and Example 6.

[0080] Example 8. FIG. 10 is a view of the configuration of the wide-band source estimating means 14 in the wide-band speech recovery device of Example 8 of the present invention. In the figure, the new parts are the up-sampling means of 49 and the zeroing means of 50. The overall configuration is the same as in FIG. 1, so its explanation will be omitted.

[0081] Below, the operation of one example of the present

invention will be explained using FIG. 10. The narrow-band source signal 6 is input into the up-sampling means 49. The up-sampling means 49 up-samples the narrow-band source signal 6 M-fold and outputs the obtained signal to the source analysis means 21. The narrow-band long-period predictive analysis means 37 within the source analysis means 21 performs long-period predictive analysis on the output signal of the up-sampling means 49 and outputs the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39. Note that the range of search of the delay in the long-period predictive analysis is M-times that of the case of Example 5. The long-period inverse filter 40 within the source analysis means 21 uses the narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39 for inverse filtering of the output signal of the up-sampling means 49 and outputs the obtained signal as the narrow-band long-period predictive residual signal 41 to wide-band long-period predictive residual estimating means 42.

[0082] The zeroing means 50 within the wide-band long-period predictive residual estimating means 42 leaves only every other M samples of the signal of the narrow-band long-period predictive residual signal 41 and makes the values of the remaining signal zero. It outputs the obtained signal as the wide-band long-period predictive residual signal 48. The wide-band long-period prediction parameter estimating means 44 outputs the narrow-band long-period delay 38 as the wide-band long-period delay 45 as it is and multiplies the narrow-band long-period prediction coefficient 39 by g and outputs the result as a wide-band long-period prediction coefficient 46. g is the same as that of Example 5. Finally, the long-period synthesis filter 47 uses the wide-band long-period delay 45 and the wide-band long-period prediction coefficient 46 for long-period synthesis filtering of the wide-band long-period

predictive residual signal 48 and outputs the obtained signal as a wide-band source signal 16.

[0083] By configuring the example in this way, a signal of a high frequency can be subjected to long-period analysis, so there are the effects that the delay can be analyzed with a higher precision, the feature relating to the strength and fluctuation of pitch periodicity of the narrow-band source signal can be reflected more finely into the wide-band source signal, a diversely changing source can be sufficiently estimated, and good quality wide-band speech can be recovered. Note that there are also the same effects as Example 5.

[0084] Example 9. FIG. 11 is a view of the configuration of the wide-band speech recovery device of Example 9 of the present invention. In the figure, the new parts are the narrow-band power calculating means of 51, the narrow-band source power of 52, and the narrow-band power-inclusive spectrum codebook of 53. The rest is the same as explained above, so only the parts somewhat different in operation will be explained.

[0085] Below, the operation of one example of the present invention will be explained using FIG. 11. The narrow-band power calculating means 51 within the analysis means 2 calculates the power contained in the amplitude information of the narrow-band source signal 6 and outputs it as the narrow-band source power 52. Note that the spectrum parameter 4 and the narrow-band source signal 6 are also output. The vector quantizing means 8 within the wide-band spectrum estimating means 7 uses the narrow-band power-inclusive spectrum codebook 53 to vector-quantize the narrow-band spectrum parameter 4 and the narrow-band source power 52 collectively and outputs the obtained spectrum code 10 to the inverse quantizing means 11 within the wide-band spectrum estimating means 7.

[0086] Here, the narrow-band power-inclusive spectrum

codebook 53 is created by the same method as Reference 1 using as learning data the pair of the narrow-band spectrum parameter obtained by analyzing many narrow-band speech signals and the narrow-band source power. As the scale of distance in the vector quantizing means 8 at the time of learning of the narrow-band power-inclusive spectrum codebook 53, it is also possible to use the use the sum of the Euclidean distance of the log of power multiplied w-fold and the Euclidean distance of the spectrum parameter.
[0087] Note that the narrow-band power calculating means 51 can calculate the power of the narrow-band speech signal 1 instead of the narrow-band source signal 6 and use this instead of said narrow-band source power 52. In this case, it uses the pair of the narrow-band spectrum parameter and the power of the narrow-band speech signal as learning data for learning of the narrow-band power-inclusive spectrum codebook 53.
[0088] By configuring the example in this way, in addition to the effects of Example 1, there are the effects that information relating to the power is reflected in the estimation of the wide-band spectrum parameter and a good spectrum can be estimated more stably.
[0089] Example 10. FIG. 12 is a view of the configuration of the wide-band speech recovery device of Example 10 of the present invention. In the figure, the new parts are the source normalizing means of 54, the narrow-band normalized source signal of 55, the wide-band normalized source signal of 56, the wide-band power codebook of 57, the wide-band source power of 58, and the wide-band source power estimating means of 59 contained in the wide-band spectrum estimating means. The rest is the same as explained above, so its explanation will be omitted.
[0090] Below, the operation of one example of the present invention will be explained using FIG. 12. The source normalizing means 54 within the analysis means 2 calculates

the power contained in the amplitude information of the narrow-band source signal 6 and outputs it as the narrow-band source power 52 to the wide-band source power estimating means 59 and outputs the signal normalizing the power of the narrow-band source signal 6 as the narrow-band normalized source signal 55 to the wide-band source estimating means 14.

[0091] The vector quantizing means 8 in the wide-band source power estimating means 59 which is actually in the wide-band spectrum estimating means 7 uses the narrow-band power-inclusive spectrum codebook 53 to vector-quantize the narrow-band spectrum parameter 4 and the narrow-band source power 52 collectively and outputs the obtained spectrum code 10 to the inverse quantizing means 11 within the wide-band source power estimating means 59. The inverse quantizing means 11 decodes the spectrum code 10 using the wide-band power codebook 57 and outputs the obtained wide-band source power 58.

[0092] The wide-band source estimating means 14 uses the narrow-band normalized source signal 54 to estimate the wide-band normalized source signal 56. Note that the estimation in the wide-band spectrum estimating means 7 and the wide-band source estimating means 14 may be performed using the same methods as Example 1 to Example 8. Further, the means multiplies this wide-band normalized source signal 56 with said wide-band source power 58 to generate the wide-band source signal 16.

[0093] By configuring the example in this way, in addition to the effects of Example 1, there are the effects that it is possible to reflect differences in a spectrum parameter in the estimation of wide-band source power and wide-band speech with a more correct amplitude can be recovered.

[0094] Example 11. FIG. 13 is a view of the configuration of the wide-band speech recovery device of Example 11 of the present invention. In the figure, the new part is the

wide-band power-inclusive spectrum codebook of 60. The rest is the same as in FIG. 11 and FIG. 12, so only parts somewhat different in operation will be explained.

[0095] Below, the operation of one example of the present invention will be explained using FIG. 13. The inverse quantizing means 11 within the wide-band spectrum estimating means 7 uses the wide-band power-inclusive spectrum codebook 60 to decode the spectrum code 10 and outputs the obtained wide-band spectrum parameter 13 and wide-band source power 58. Here, the wide-band power-inclusive spectrum codebook 60 is created by the same method as Reference 1 using as learning data the pair of the wide-band spectrum parameter obtained by analysis of many wide-band speech signals and the wide-band source power. For the scale of distance, the same one as used for creation of the narrow-band power-inclusive spectrum codebook 53 is used.

[0096] By configuring the example in this way, it is possible to give the effects of Example 9 and Example 10.

[0097] Example 12. FIG. 14 is a view of the configuration of the wide-band speech recovery device of Example 12 of the present invention. In the figure, the new part is the post-filtering means of 61. The rest is the same as Example 1 to Example 11, so its explanation will be omitted.

[0098] Below, the operation of one example of the present invention will be explained using FIG. 14. The post-filtering means 61 performs post-filtering on the provisional wide-band speech signal which the synthesis filter 17 outputs and outputs the obtained signal to the band-pass filter 18. The band-pass filter 18 filters the signal which the post-filtering means 61 outputs to extract components other than the band of the components of narrow-band speech. Note that post-filtering is signal processing which improves the audible quality and the pitch periodicity or spectrum poles, enhances the high band to

improve the clarity, or suppresses a band with large distortion occurring when traveling through a transmission line so as to reduce the feeling of distortion. As processing for enhancement of the pitch periodicity, the method of multiplying the provisional wide-band speech signal exactly the pitch period before by a coefficient smaller than 1 and adding this to the current provisional wide-band speech signal is common.

[0099] As the pole enhancement, the method of modifying the wide-band spectrum parameter 13 to calculate the filter coefficient of a pole-zero type filter which has a large gain in the frequency band near the polar frequency of the wide-band spectrum parameter 13 and has a small gain in frequency bands other than near the poles of the wide-band spectrum parameter 13 has been variously proposed. It can be realized by applying this filter to the provisional wide-band speech signal. Moreover, the distortion occurring when passing through a transmission line is large in the small amplitude frequency bands, i.e., the frequency bands other than near the poles, so this pole enhancement can suppress bands with large distortion. As high-band enhancement, the method called "pre-emphasis", i.e., the method of multiplying the provisional wide-band speech signal of one point before with a coefficient of 1 or less and subtracting the result from the current provisional wide-band speech signal, is common. Moreover, in FIG. 14, the post-filtering means 61 and the band-pass filter 18 may be reversed in positions or the post-filtering means 61 may be applied to the wide-band speech signal 20.

[0100] By configuring the example in this way, in addition to the effects of Example 1, there is the effect that when the quality of the recovered wide-band speech signal is insufficient, it is possible to the enhance the pitch periodicity of the wide-band speech signal or spectrum poles, enhance the high band to improve the clarity, or

suppress bands with large distortion occurring when passing through a transmission line to reduce the feeling of distortion. Note that in FIG. 14 it is also possible to remove the inverse filter 5 and the wide-band source estimating means 14. This configuration corresponds to application of the present invention to Reference 1 and has the same effects as the above.

[0101] Example 13. The wide-band spectrum estimating means 7 of Example 1 to Example 12 can also be configured to output the narrow-band spectrum parameter 4 as a wide-band spectrum parameter 13 as it is.

[0102] FIG. 15 is an explanatory view explaining the relation of the general shapes of the narrow-band spectrum and the wide-band spectrum in this case. When the spectrum envelope which the narrow-band spectrum parameter 4 expresses is FIG. 15(a), if using this as the wide-band spectrum parameter 13 as it is, as a result the width extends and the spectrum envelope which the wide-band spectrum parameter 13 expresses becomes in form FIG. 15(a) stretched M-fold in the frequency axis direction, that is, becomes as shown in FIG. 15(b) when M is 2. Therefore, in the case of a high 2 kHz to 3.4 kHz of the narrow-band spectrum envelope, the high band of 3.4 kHz or more which is recovered also becomes higher. Conversely when a low 2 kHz to 3.4 kHz, the high band also becomes lower. As a result, the general inclination of the narrow-band spectrum envelope will be reflected in the high band as it is.

[0103] By configuring the example in this way, in addition to the effects of Example 1, there is the effect that, while general, the wide-band spectrum can be recovered very easily. Compared with Example 1, there are the effects that no memory is necessary for storing the codebooks and the amount of processing becomes smaller.

[0104] Example 14. In Example 1 to Example 12, the wide-band spectrum estimating means 7 can also be configured to

output from the lowest degree to a predetermined degree of the narrow-band spectrum parameter 4 as the wide-band spectrum parameter 13. However, the narrow-band spectrum parameter 4 which the spectrum analysis means 3 outputs is restricted to a parameter like a PARCOR coefficient or an auto correlation coefficient where synthesis is always stable even when using the lowest degree to a predetermined degree taken out as the wide-band spectrum parameter 13.

[0105] FIG. 16 is an explanatory view explaining the relation of the general shapes of the narrow-band spectrum and the wide-band spectrum in this case. In the case where the spectrum envelope which the narrow-band spectrum parameter 4 expresses is FIG. 15(a), if using the lowest degree to a predetermined degree as the wide-band spectrum parameter 13, the spectrum envelope which the wide-band spectrum parameter 13 expresses becomes in form FIG. 15(a) extended M-fold in the frequency axis direction and further with the pole structures made smoother, that is, becomes as shown in FIG. 15(b) when M is 2. As a result, the general inclination of the narrow-band spectrum envelope is reflected in the high band as it is and the generation of a strong pole which did not exist in the past in the high band and the generation of unnatural recovered sound can be suppressed.

[0106] By configuring the example in this way, in addition to the effects of Example 13, there is the effect that the generation of a nonexisting strong pole in the high band and the generation of unnatural recovered sound, which sometimes occurred in the case of Example 13, can be suppressed.

[0107] Example 15. FIG. 17 is a view of the configuration of the wide-band spectrum estimating means 7 of the wide-band speech recovery device of Example 15 of the present invention. In the figure, the new parts are the spectrum parameter converting means of 62, the degree reducing means

of 63, and the spectrum parameter inverse converting means of 64. The rest is the same as in Example 1 to Example 12, so its explanation will be omitted.

[0108] Below, the operation of one example of the present invention will be explained using FIG. 17. The spectrum parameter converting means 62 within the wide-band spectrum estimating means 7 converts the narrow-band spectrum parameter 4 to a parameter like the PARCOR coefficient or an auto correlation coefficient for which synthesis is always stable when taking out the lowest degree to a predetermined degree. The degree reducing means 63 outputs the lowest degree to a predetermined degree of the parameter which the spectrum parameter converting means 62 outputs to the spectrum parameter inverse converting means 64. The spectrum parameter inverse converting means 64 returns the parameter which the degree reducing means 63 outputs to the same domain as the narrow-band spectrum parameter 4 and outputs it as the wide-band spectrum parameter 13.

[0109] By configuring the example in this way, the same effects as in Example 14 can be obtained even when the narrow-band spectrum parameter 4 is a parameter for which synthesis is unstable when taken out from the lowest degree to a predetermined degree.

[0110] Example 16. In Example 14 and Example 15, a strong pole was suppressed by degree reduction, but it is also possible to use the method of using an auto correlation coefficient as the spectrum parameter and applying a lag window to this or giving similar effects. By configuring the example in this way, there is the effect that the same effects as in Example 14 are obtained with other means. Note that it is also possible to apply the wide-band spectrum estimating means 7 of Examples 13 to 16 to the conventional configuration of Reference 1 etc. For example, the overall configuration when applied to Reference 1

becomes FIG. 14 minus the inverse filter 5, the wide-band source estimating means 14, and the post-filtering means 61. By configuring the example in this way, the effects newly created in Examples 13 to 16 can be added to the prior art.

[0111] Example 17. In the following example, the example of applying the present invention to a device for recovering wide-band speech based on the encoded information by transmission etc. will be explained. FIG. 18 is a view of the configuration of the wide-band speech recovery device of Example 17 of the present invention. In the figure, 101 is a narrow-band speech code, 102 is a separating means, 103 is a narrow-band spectrum code, 104 is a narrow-band source code, 105 is a wide-band spectrum decoding means, 106 is a wide-band source decoding means, 107 is a narrow-band spectrum decoding means, 108 is a narrow-band source decoding means, and 109 is a narrow-band speech decoding means. The rest is the same as in Example 1 to Example 16, so its explanation will be omitted. In this example as well, a good wide-band source signal is obtained without reanalysis.

[0112] Below, the operation of one example of the present invention will be explained using FIG. 18. First, the narrow-band speech code 101 is input into the separating means 102 and the narrow-band speech decoding means 109. This narrow-band speech code 101 is a narrow-band speech signal sampled at for example 8 kHz, restricted to the 300 Hz to 3.4 kHz telephone band, and separately encoded and is input from a storage recording medium or a communications line. The separating means 102 separates the narrow-band speech code 101 into the narrow-band spectrum code 103 and the narrow-band source code 104, outputs the narrow-band spectrum code 103 to the wide-band spectrum decoding means 105, and outputs the narrow-band source code 104 to the wide-band source decoding means 106.

[0113] The narrow-band spectrum decoding means 107 within the wide-band spectrum decoding means 105 decodes the narrow-band spectrum code 103 and outputs the obtained narrow-band spectrum parameter 4. Note that the narrow-band spectrum decoding means 107 need only perform processing the reverse of the coding processing of the narrow-band spectrum parameter used when encoding the narrow-band speech code 101. Further, the wide-band spectrum estimating means 7 within the wide-band spectrum decoding means 105 uses said narrow-band spectrum parameter 4 to estimate the wide-band spectrum parameter 13. Note that as the wide-band spectrum estimating means 7, it is possible to use a method described in the examples explained up until now.

[0114] The narrow-band source decoding means 108 within the wide-band source decoding means 106 decodes said narrow-band source code 104 and outputs the obtained narrow-band source signal 6. Further, the wide-band source estimating means 14 within the wide-band source decoding means 106 uses said narrow-band source signal 6 to estimate the wide-band source signal 16. Note that for the wide-band source estimating means 14, the zero-stuffing means etc. can be used. The narrow-band source decoding means 108 need only perform processing the reverse of the coding processing of the narrow-band source signal used when encoding the narrow-band speech code 101.

[0115] The synthesis filter 17 using the wide-band spectrum parameter 13 for synthesis filtering of the wide-band source signal 16 to generate the provisional wide-band speech signal. The band-pass filter 18 filters this provisional wide-band speech signal to extract components other than the bands with the components of narrow-band speech. When the band of the wide-band speech signal is 0 Hz to 7.3 kHz, the components of 0 Hz to 300 Hz and 3.4 kHz to 7.3 kHz are extracted.

[0116] On the other hand, the narrow-band speech decoding

means 109 decodes the input narrow-band speech code 101 and outputs the obtained narrow-band speech signal 1 to the up-sampling means 19. This decoding processing need only performing processing the reverse of the coding processing used when encoding the narrow-band speech code 101. Next, the up-sampling means 19 up-samples the narrow-band speech signal 1 M-fold. The signal generated by the up-sampling has a sampling frequency the same as that of the wide-band speech signal 20 and has the same narrow-band components as the narrow-band speech signal 1. Further, the device adds the output of the band-pass filter 18 and the output of the up-sampling means 19 to generate the wide-band speech signal 20.

[0117] By configuring the example in this way, there is the effect that when receiving a narrow-band speech code from a storage medium or a communication line, the narrow-band speech does not have to be reanalyzed, so recovery is possible by a small amount of processing. Moreover, there is the effect that since no distortion is superimposed due to interpolation at the time of synthesis, framing at the time of analysis, etc., better quality wide-band speech can be recovered. Note that this also has the same effects as Example 1.

[0118] Note that it is also possible for the narrow-band speech decoding means 109 to receive as input the narrow-band spectrum parameter 4 and the narrow-band source signal 6 and synthesize the narrow-band speech signal 1. Conversely, it is also possible to input the narrow-band spectrum parameter 4 and the narrow-band source signal 6 calculated as intermediate parameters of the decoding process within the narrow-band speech decoding means 109 to the wide-band spectrum decoding means 105 and the wide-band source decoding means 106. In this case, there are the effects that superfluous processing can be eliminated and wide-band speech can be recovered by a still smaller amount

of processing. Moreover, when the pitch period code and power code can be separated from the narrow-band speech code 101, it is also possible to decode the pitch period and power information from these codes and use said wide-band spectrum parameter 13 and this pitch period and power information to generate the provisional wide-band synthesized sound by the same method as Reference 1.

[0119] Example 18. FIG. 19 is a view of the configuration of the wide-band source decoding means 106 of the wide-band speech recovery device of Example 18 of the present invention. In the figure, the new parts are the narrow-band pitch code of 110, the narrow-band power code of 111, the wide-band pitch decoding means of 112, the wide-band pitch period of 113, the wide-band power decoding means of 114, the wide-band power of 115, and the source generating means of 116. The rest is the same as Example 17, so its explanation will be omitted.

[0120] This example is limited to the case of input of a narrow-band speech code 101 where the narrow-band pitch code 110 and the narrow-band power code 111 can be easily separated by said separating means 102. In this case, the configuration of FIG. 19 has meaning. Below, the operation of one example of the present invention will be explained using FIG. 19. As a narrow-band source code 104, the narrow-band pitch code 110 and the narrow-band power code 111 are input into the wide-band source decoding means 106.

[0121] The wide-band pitch decoding means 112 within the wide-band source decoding means 106 uses the narrow-band pitch code 110 to estimate the wide-band pitch period 113. As the estimation method, it is possible to decode the narrow-band pitch period from the narrow-band pitch code 110 and multiple that value by M, but it is also possible to hold the results as a table and find a specific value by reading the table component corresponding to the narrow-band pitch code 110. Next, the wide-band power decoding

means 114 within the wide-band source decoding means 106 uses the narrow-band power code 111 to estimate the wide-band power 115. As the estimation method, it is possible to decode the narrow-band power from the narrow-band power code 111 and multiple that value by g, but it is also possible to hold the results as a table and find a specific value by reading the table component corresponding to the narrow-band power code 111.

[0122] The source generating means 116 outputs a signal rearranging the fixed sources using the wide-band pitch period 113 as a repeating period and finally multiplies the output signal of this source generating means 116 with the wide-band power 115 and outputs the result as the wide-band source signal 16.

[0123] By configuring the example in this way, in addition to the effects of Example 17, there is the effect that since the wide-band source signal 16 is generated directly without decoding the narrow-band source signal, recovery is possible by a small amount of processing.

[0124] Example 19. FIG. 20 is a view of the configuration of the wide-band source decoding means 106 of the wide-band speech recovery device of Example 19 of the present invention. In the figure, the new parts are the narrow-band adaptive source code of 117, the narrow-band excitation source code of 118, the wide-band adaptive source decoding means of 119, the wide-band excitation source decoding means of 120, the narrow-band adaptive source decoding means of 121, and the narrow-band excitation source decoding means of 122. The rest is the same as that explained above, so its explanation will be omitted.

[0125] This example is limited to the case of input of a narrow-band speech code 101 where the narrow-band adaptive source code 117 and the narrow-band excitation source code 118 can be easily separated from the narrow-band speech code of the input by said separating means 102. In this

case, the configuration of FIG. 20 has meaning. Below, the operation of one example of the present invention will be explained using FIG. 20. As the narrow-band source code 104, the narrow-band adaptive source code 117 and the narrow-band excitation source code 118 are input to the wide-band source decoding means 106.

[0126] The narrow-band adaptive source decoding means 121 within the wide-band adaptive source decoding means 119 decodes said narrow-band adaptive source code 117 and outputs the narrow-band adaptive lag length 25 and the narrow-band adaptive gain 26 obtained. The wide-band adaptive source estimating means 30 within the wide-band adaptive source decoding means 119 generates and outputs the wide-band adaptive source signal 32 from this narrow-band adaptive lag length 25 and the narrow-band adaptive gain 26. The operation of the wide-band adaptive source estimating means 30 is the same as that of Example 2.

[0127] The narrow-band excitation source decoding means 122 within the wide-band excitation source decoding means 120 decodes said narrow-band excitation source code 118 and outputs the obtained narrow-band excitation source signal 24. The wide-band excitation source estimating means 27 within the wide-band excitation source decoding means 120 estimates and outputs the wide-band excitation source signal 29 from this narrow-band excitation source signal 24. The operation of the wide-band excitation source estimating means 27 is the same as that of Example 2 to Example 4. Finally, the device adds the wide-band adaptive source signal 32 and the wide-band excitation source signal 29 and outputs the result as the wide-band source signal 16.

[0128] By configuring the example in this way, in addition to the effects of Example 2 to Example 4 and Example 17, there is the effect that since the wide-band source signal 16 is generated directly without decoding the narrow-band

source signal, recovery is possible by a small amount of processing. Furthermore, the basic frequency and the frequencies of its harmonic components are correctly arranged at whole multiple positions, so the relation of the narrow-band component and the recovered wide-band component in the wide-band speech signal finally recovered is good, and high quality wide-band speech can be recovered. Furthermore, since neither voiced/unvoiced information nor pitch period information is used, even a source with intermediate properties can be expressed, there are the effects that there is no effect of voiced/unvoiced judgment error or pitch extraction error which tends to occur in a narrow-band speech signal where noise is superimposed, a good wide-band source can be estimated even near the voiced/unvoiced boundary, and stable, natural quality wide-band speech can be recovered.

[0129] Example 20. FIG. 21 is a view of the configuration of the wide-band source decoding means 106 of the wide-band speech recovery device of Example 20 of the present invention. In the figure, the new parts are the narrow-band long-period predictive code of 123, the wide-band long-period prediction parameter (code) decoding means of 124, the narrow-band long-period prediction parameter (code) decoding means of 125, the narrow-band long-period predictive residual code of 126, the wide-band long-period predictive residual decoding means of 127, and the narrow-band long-period predictive residual decoding means of 128. The rest is the same as explained above, so its explanation will be omitted.

[0130] This example is limited to the case of input of a narrow-band speech code 101 where the narrow-band long-period predictive code 123 and the narrow-band long-period predictive residual code 126 can be easily separated from the narrow-band speech code of input by the separating means 102. In this case, the configuration of FIG. 21 has

meaning. Below, the operation of one example of the present invention will be explained using FIG. 21. As the narrow-band source code 104, the narrow-band long-period predictive code 123 and the narrow-band long-period predictive residual code 126 are input into the wide-band source decoding means 106.

[0131] The narrow-band long-period prediction parameter decoding means 125 within the wide-band long-period prediction parameter (code) decoding means 124 decodes said narrow-band long-period predictive code 123 and outputs the narrow-band long-period delay 38 of one of the obtained predictive codes and the narrow-band long-period prediction coefficient 39 of the other predictive code. The wide-band long-period prediction parameter estimating means 44 within the wide-band long-period prediction parameter decoding means 124 estimates and outputs the wide-band long-period delay 45 of one of the long-period predictive codes and the wide-band long-period prediction coefficient 46 of the other of the long-period predictive codes from this narrow-band long-period delay 38 and the narrow-band long-period prediction coefficient 39. The operation of the wide-band long-period prediction parameter estimating means 44 is the same as that of Example 5.

[0132] The narrow-band long-period predictive residual decoding means 128 within the wide-band long-period predictive residual decoding means 127 decodes said narrow-band long-period predictive residual code 126 and outputs the obtained narrow-band long-period predictive residual signal 41. The wide-band long-period predictive residual estimating means 42 within the wide-band long-period predictive residual decoding means 127 estimates and outputs the wide-band long-period predictive residual signal 48 from this narrow-band long-period predictive residual signal 41. The operation of the wide-band long-period predictive residual estimating means 42 is the same

as that of Example 5 to Example 7. Finally, the long-period synthesis filter 47 uses the wide-band long-period delay 45 and the wide-band long-period prediction coefficient 46 for long-period synthesis filtering of the wide-band long-period predictive residual signal 48 and outputs the obtained signal as the wide-band source signal 16.

[0133] By configuring the example in this way, in addition to the effects of Example 5 to Example 7 and Example 17, since the wide-band source signal 16 is generated directly without decoding the narrow-band source signal, there is the effect that recovery is possible with a small amount of processing.

[0134] Example 21. Example 17 to Example 20 decode the narrow-band spectrum parameter 4 from the narrow-band spectrum code 103, then estimate the wide-band spectrum parameter 13, but it is also possible to refer to a wide-band spectrum codebook by the narrow-band spectrum code 103 so as to calculate the wide-band spectrum parameter 13 directly. By configuring the example in this way, in addition to the effects of Example 17 to Example 20, there is the effect that recovery is possible with a still smaller amount of processing.

[0135] Example 22. FIG. 22 is a view of the configuration of the wide-band speech recovery device of one example of the present invention. In the figure, the new parts are the narrow-band power decoding means of 129 and the wide-band normalized source decoding means of 130. The wide-band spectrum estimating means 7 is the same as that of Example 11. The rest is the same as that explained above, so its explanation will be omitted.

[0136] Below, the operation of one example of the present invention will be explained using FIG. 22. The narrow-band power decoding means 129 decodes the part relating to power from the narrow-band amplitude information included in the narrow-band source code 104 and outputs the obtained

narrow-band source power 52 to the wide-band spectrum estimating means 7. The wide-band spectrum estimating means 7 uses the narrow-band spectrum parameter 4 and the narrow-band source power 52 to estimate the wide-band spectrum parameter 13 and the wide-band source power 58. The wide-band normalized source decoding means 130 uses the parts other than the part relating to the narrow-band power contained in the narrow-band source code 104 to estimate the wide-band source signal normalized in power and outputs it as the wide-band normalized source signal 56. The processing in this wide-band normalized source decoding means 130 may be made the same as in Example 18 to Example 20. Further, this wide-band normalized source signal 56 is multiplied with said wide-band source power 58 to generate the wide-band source signal 16.

[0137] By configuring the example in this way, it is possible to obtain the combined effects of Example 11 and Example 18 to Example 20. Note that like in Example 9 or Example 10, the wide-band spectrum estimating means 7 may also estimate just one of the wide-band spectrum parameter 13 or the wide-band source power 58.

[0138] Example 23. In Example 17 to Example 22, it is also possible to insert the post-filtering means 61 between the synthesis filter 17 and the band-pass filter 18. Moreover, it is also possible for the post-filtering means 61 and the band-pass filter 18 to be reversed in position and possible for the post-filtering means 61 to be applied to the wide-band speech signal 20. By configuring the example in this way, when post-filter processing is performed in the narrow-band speech decoding means 109, there is the effect that has the continuity of the narrow-band section and the recovered band can be improved. Moreover, it is possible to obtain the combined effects of Example 12 and Example 17 to Example 22.

[0139] Example 24. In the configuration of FIG. 18 minus

the wide-band source decoding means 106, it is also possible to insert the post-filtering means 61 between the synthesis filter 17 and the band-pass filter 18. Further, it is also possible for the post-filtering means 61 and the band-pass filter 18 to be reversed in position and possible for the post-filtering means 61 to be applied to the wide-band speech signal 20. This configuration corresponds to application of claim 9 and claim 15 of the present invention to Reference 1. When post-filter processing is performed in the narrow-band speech decoding means 109, there is the effect that has the continuity of the narrow-band section and the recovered band can be improved.

[0140]

[Effects of the Invention] As explained above, according to the present invention, a narrow-band source signal is used to estimate a wide-band source signal and this is used to synthesize a wide-band speech signal, so there are the effects that the feature of the narrow-band source signal can be given well to the wide-band source signal, there is little dependency on the speaker, and stable natural quality wide-band speech can be recovered.

[0141] Moreover, as the wide-band source estimating means, a zero stuffing means for inserting predetermined numbers of zeros between samples of the narrow-band source signal was used, so there are the effects that voiced/unvoiced judgment and pitch extraction are unnecessary, a good wide-band source free of any effect of voiced/unvoiced judgment error or pitch extraction error can be estimated, and stable, natural quality wide-band speech can be recovered.

[0142] Moreover, the wide-band source estimating means is made one which uses a narrow-band adaptive source code and a narrow-band excitation source signal to estimate a wide-band adaptive source signal and a wide-band excitation source signal and to generate a wide-band source signal using these, so there are the effects that the feature

relating to the strength and fluctuation of pitch periodicity which a narrow-band source signal has is reflected in the wide-band source signal well, there is also no pulse-like sound, and good quality wide-band speech can be recovered. Furthermore, since the basic frequency and the frequencies of the harmonic components are correctly arranged at whole multiple positions, the relation of the narrow-band component and a recovered wide-band component in a wide-band speech signal is good, the actual property of pitch periodicity can also be recovered, and high quality wide-band speech can be recovered.

[0143] Moreover, the wide-band source estimating means is made one which uses a narrow-band long-period predictive code and a narrow-band long-period residual signal to estimate a wide-band long-period predictive code and a wide-band long-period residual signal and to generate a wide-band source signal using these, so there are the effects that the feature relating to the strength and fluctuation of pitch periodicity which a narrow-band source signal has is reflected in the wide-band source signal well, there is also no pulse-like sound, and good quality wide-band speech can be recovered. Furthermore, since the basic frequency and the frequencies of the harmonic components are correctly arranged at whole multiple positions, the relation of the narrow-band component and a recovered wide-band component in a wide-band speech signal finally recovered is good, the actual property of pitch periodicity can also be recovered, and high quality wide-band speech can be recovered.

[0144] Moreover, since a narrow-band spectrum parameter and narrow-band amplitude information are used to estimate one or both of a wide-band spectrum parameter and wide-band amplitude information, there are the effects that the narrow-band amplitude information is reflected in the estimation of the wide-band spectrum parameter, a good

spectrum can be estimated more stably, and wide-band speech with more correct amplitude can be recovered.

[0145] Furthermore, a wide-band speech signal estimated using a narrow-band speech signal is post-filtered, so there is the effect that when the quality of the recovered wide-band speech signal is insufficient, the pitch periodicity can be enhanced, the poles of the spectrum envelope can be enhanced, and the quality can otherwise be improved.

[0146] Furthermore, the narrow-band spectrum parameter is extended and used as a wide-band spectrum parameter to synthesize wide-band speech signal, so there is the effect that the general wide-band spectrum can be recovered very easily. Moreover, there are the effects that no memory for storing codebooks is necessary and the amount of processing becomes smaller.

[0147] Furthermore, up to a predetermined degree of the narrow-band spectrum parameter is used and this is inversely converted to a spectrum parameter to obtain the wide-band spectrum parameter, so there is the effect that the general wide-band spectrum can be recovered very easily. Moreover, there are the effects that no memory for storing codebooks is necessary and the amount of processing becomes smaller.

[0148] Moreover, according to the present invention, a narrow-band speech code is used to generate narrow-band synthesized sound and estimate a wide-band speech signal and components of bands other than the narrow-band synthesized sound of the wide-band speech signal are extracted and added to the signal obtained up-sampling the narrow-band synthesized sound or the narrow-band synthesized sound, so there are the effects that wide-band speech can be recovered even from encoded narrow-band speech and that the decoded narrow-band speech is not reanalyzed, so recovery is possible with a small amount of

processing.

[0149] Moreover, a wide-band spectrum parameter estimated using a narrow-band spectrum code and a wide-band source signal estimated using a narrow-band source code are used to synthesize a wide-band speech signal, so there are the effects that the decoded narrow-band speed does not have to be reanalyzed and recovery is possible by a small amount of processing. Moreover, there is the effect that there is no distortion due to interpolation at the time of synthesis, framing at the time of analysis, etc. superimposed, so better quality wide-band speech can be recovered.

[0150] Moreover, as the wide-band source decoding means, a zero stuffing means for inserting predetermined numbers of zeros between samples of the narrow-band source decoded using a narrow-band source code was used, so there are the effects that even a source with properties between voiced and unvoiced sources can be recovered well and stable, natural quality wide-band speech can be recovered.

[0151] Moreover, the wide-band source decoding means is made one which estimates a wide-band adaptive source signal and a wide-band excitation source signal estimated using a narrow-band source code and adds these to obtain a wide-band source signal, so there are the effects that a wide-band source signal is generated directly without decoding a narrow-band source signal and recovery is possible with a small amount of processing. Moreover, the feature relating to the strength and fluctuation of pitch periodicity which the narrow-band source code includes is reflected in the wide-band source signal well, so there is the effect that good quality wide-band speech can be recovered.

[0152] Moreover, the wide-band source decoding means is made one which estimates a wide-band long-period predictive code and wide-band long-period residual signal estimated using a narrow-band source code and uses these to synthesize a wide-band source signal, so there are the

effects that a wide-band source signal is generated directly without decoding a narrow-band source signal and recovery is possible with a small amount of processing. Moreover, the feature relating to the strength and fluctuation of pitch periodicity which the narrow-band source code includes is reflected in the wide-band source signal well, so there is the effect that good quality wide-band speech can be recovered.

[0153] Moreover, a narrow-band spectrum code and narrow-band amplitude information are used to estimate one or both of a wide-band spectrum parameter and wide-band amplitude information, so there are the effects that the narrow-band amplitude information can be reflected in the estimation of the wide-band spectrum parameter, a good spectrum can be estimated more stably, and differences in a narrow-band spectrum code can be reflected in estimation of the wide-band amplitude information, so wide-band speech with more correct amplitude can be recovered.

[0154] Furthermore, a wide-band speech signal estimated using a narrow-band speech signal is post-filtered, so there is the effect that the continuity of the narrow-band part and the recovered band becomes better when applying post-filtering to the narrow-band synthesized sound. Further, when the quality of the recovered wide-band speech signal is insufficient, the pitch periodicity can be enhanced, the poles of the spectrum envelope can be enhanced, and the quality can otherwise be improved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] A view of the configuration of a wide-band speech recovery device of Example 1 of the present invention.

[FIG. 2] An explanatory view explaining the processing of a zero-stuffing means in Example 1 of the present invention.

[FIG. 3] A view of the configuration of a wide-band source estimating means in the wide-band speech recovery device of Example 2 of the present invention.

[FIG. 4] An explanatory view explaining an example of an adaptive source signal in Example 2 of the present invention.

[FIG. 5] A view of the configuration of a wide-band excitation source estimating means in the wide-band speech recovery device of Example 3 of the present invention.

[FIG. 6] A view of the configuration of a wide-band excitation source estimating means in the wide-band speech recovery device of Example 4 of the present invention.

[FIG. 7] A view of the configuration of a wide-band source estimating means in the wide-band speech recovery device of Example 5 of the present invention.

[FIG. 8] A view of the configuration of a wide-band excitation source estimating means in the wide-band speech recovery device of Example 6 of the present invention.

[FIG. 9] A view of the configuration of a wide-band excitation source estimating means in the wide-band speech recovery device of Example 7 of the present invention.

[FIG. 10] A view of the configuration of a wide-band source estimating means in the wide-band speech recovery device of Example 8 of the present invention.

[FIG. 11] A view of the configuration of a wide-band speech recovery device of Example 9 of the present invention.

[FIG. 12] A view of the configuration of a wide-band speech recovery device of Example 10 of the present invention.

[FIG. 13] A view of the configuration of a wide-band speech recovery device of Example 11 of the present invention.

[FIG. 14] A view of the configuration of a wide-band speech recovery device of Example 12 of the present invention.

[FIG. 15] An explanatory view explaining the relation of the general shapes of the narrow-band spectrum and wide-band spectrum in Example 13 of the present invention.

[FIG. 16] An explanatory view explaining the relation of the general shapes of the narrow-band spectrum and wide-band spectrum in Example 14 of the present invention.

[FIG. 17] A view of the configuration of a wide-band spectrum estimating means in the wide-band speech recovery device of Example 15 of the present invention.

[FIG. 18] A view of the configuration of the wide-band speech recovery device of Example 17 of the present invention.

[FIG. 19] A view of the configuration of a wide-band source decoding means in the wide-band speech recovery device of Example 18 of the present invention.

[FIG. 20] A view of the configuration of a wide-band source decoding means in the wide-band speech recovery device of Example 19 of the present invention.

[FIG. 21] A view of the configuration of a wide-band source decoding means in the wide-band speech recovery device of Example 20 of the present invention.

[FIG. 22] A view of the configuration of the wide-band speech recovery device of Example 22 of the present invention.

[Description of Notations]

1... narrow-band speech signal, 2... analysis means, 3... spectrum analysis means, 4... a narrow-band spectrum parameter, 5... an inverse filter, 6... a narrow-band source signal, 7... a wide-band spectrum estimating means, 8... a vector quantizing means, 9... a narrow-band spectrum codebook, 10... spectrum code, 11... an inverse quantizing means, 12... a wide-band spectrum codebook, 13... a wide-band spectrum parameter, 14... a wide-band source estimating means, 15... a zero-stuffing means, 16... a wide-band source signal, 17... a synthesis filter, 18... a band-pass filter, 19... an up-sampling means, 20... a wide-band speech signal, 21... source analysis means, 22... a narrow-band adaptive codebook, 23... a distortion minimizing means, 24... narrow-band excitation source signal, 25... a narrow-band adaptive lag length, 26... a narrow-band adaptive gain, 27... a wide-band excitation

source estimating means, 28... a zero-stuffing means, 29... a wide-band excitation source signal, 30... a wide-band adaptive source estimating means, 31... a wide-band adaptive source codebook, 32... a wide-band adaptive source signal, 33... a wide-band adaptive lag length, 34... a wide-band adaptive gain, 35... a power calculating means, 36... a noise generating means, 37... a narrow-band long-period predictive analysis means, 38... a narrow-band long-period delay, 39... a narrow-band long-period prediction coefficient, 40... a long-period inverse filter, 41... a narrow-band long-period predictive residual signal, 42... a wide-band long-period predictive residual estimating means, 43... a zero-stuffing means, 44... a wide-band long-period prediction parameter estimating means, 45... a wide-band long-period delay, 46... a wide-band long-period prediction coefficient, 47... a long-period synthesis filter, 48... a wide-band long-period predictive residual signal, 49... an up-sampling means, 50... a zeroing means, 51... a narrow-band power calculating means, 52... a narrow-band source power, 53... a narrow-band power-inclusive spectrum code, 54... a source normalizing means, 55... a narrow-band normalized source signal, 56... a wide-band normalized source signal, 57... a wide-band power codebook, 58... a wide-band source power, 59... a wide-band source power estimating means, 60... a wide-band power-inclusive spectrum codebook, 61... a post-filtering means, 62... a spectrum parameter converting means, 63... a degree reducing means, 64... a spectrum parameter inverse converting means, 101... a narrow-band speech code, 102... a separating means, 103... a narrow-band spectrum code, 104... a narrow-band source code, 105... a wide-band spectrum decoding means, 106... a wide-band source decoding means, 107... a narrow-band spectrum decoding means, 108... a narrow-band source decoding means, 109... a narrow-band speech decoding means, 110... a narrow-band pitch code,

111... a narrow-band power code, 112... a wide-band pitch decoding means, 113... a wide-band pitch period, 114... a wide-band power decoding means, 115... a wide-band power decoding means, 116... a source generating means, 117... a narrow-band adaptive source code, 118... a narrow-band excitation source code, 119... a wide-band adaptive source decoding means, 120... a wide-band excitation source decoding means, 121... a narrow-band adaptive source decoding means, 122... a narrow-band excitation sources decoding means, 123... a narrow-band long-period predictive code, 124... a wide-band long-period prediction parameter decoding means, 125... a narrow-band long-period prediction parameter decoding means, 126... a narrow-band long-period predictive residual code, 127... a wide-band long-period predictive residual decoding means, 128... a narrow-band long-period predictive residual decoding means, 129... a narrow-band power decoding means, 130... a wide-band normalized source decoding means.

[FIG. 1]

1... narrow-band speech signal
2... analysis means
3... spectrum analysis means
4... narrow-band spectrum parameter
5... inverse filter
6... narrow-band source signal
8... vector quantizing means
9... narrow-band spectrum codebook
10... spectrum code
11... inverse quantizing mean
12... wide-band spectrum codebook
13... wide-band spectrum parameter
14... wide-band source estimating means
15... zero-stuffing means
16... wide-band source signal
17... synthesis filter
18... band-pass filter
19... up-sampling means
20... wide-band speech signal

[FIG. 2]

Case of M=2

[FIG. 3]

14... wide-band source estimating means
21... source analysis means
22... narrow-band adaptive codebook
23... distortion minimizing means
24... narrow-band excitation source signal
25... narrow-band adaptive lag length
26... narrow-band adaptive gain
27... wide-band excitation source estimating means
28... zero-stuffing means
29... wide-band excitation source signal
30... wide-band adaptive source estimating means
31... wide-band adaptive source codebook

[FIG. 4]

(a) Lag length ≥ length of output signal

Past narrow-band sound signal | Output signal

Lag length | Lag length

(b) Lag length < length of output signal

Past narrow-band sound signal | Output signal

Lag length | Lag length

[FIG. 5]

24... narrow-band excitation source signal

27... wide-band excitation source estimating means

35... power calculating mean

36... noise generating means

[FIG. 6]

27... wide-band excitation source estimating means

28... zero-stuffing means

35... power calculating mean

36... noise generating means

[FIG. 7]

14... wide-band source estimating means

21... source analysis means

37... narrow-band long-period predictive analysis means

38... narrow-band long-period delay

39... narrow-band long-period prediction coefficient

40... long-period inverse filter

41... narrow-band long-period predictive residual signal

42... wide-band long-period predictive residual estimating means

43... zero-stuffing means

44... wide-band long-period prediction parameter estimating means

45... wide-band long-period delay

46... wide-band long-period prediction coefficient

47... long-period synthesis filter

48... wide-band long-period predictive residual signal

[FIG. 8]

35... power calculating mean
36... noise generating means
42... wide-band long-period predictive residual estimating means
[FIG. 9]
35... power calculating mean
36... noise generating means
42... wide-band long-period predictive residual estimating means
43... zero-stuffing means
[FIG. 10]
14... wide-band source estimating means
21... source analysis means
37... narrow-band long-period predictive analysis means
40... long-period inverse filter
42... wide-band long-period predictive residual estimating means
43... zero-stuffing means
44... wide-band long-period prediction parameter estimating means
47... long-period synthesis filter
49... up-sampling means
[FIG. 11]
2... analysis means
3... spectrum analysis means
5... inverse filter
7... wide-band spectrum estimating means
8... vector quantizing means
11... inverse quantizing mean
12... wide-band spectrum codebook
13... wide-band spectrum parameter
14... wide-band source estimating means
17... synthesis filter
18... band-pass filter
19... up-sampling means

51... narrow-band power calculating means
53... narrow-band power-inclusive spectrum code
[FIG. 12]
3... spectrum analysis means
5... inverse filter
6... narrow-band source signal
7... wide-band spectrum estimating means
8... vector quantizing means
11... inverse quantizing mean
14... wide-band source estimating means
17... synthesis filter
18... band-pass filter
19... up-sampling means
53... narrow-band power-inclusive spectrum code
54... source normalizing means
56... wide-band normalized source signal
57... wide-band power codebook
58... wide-band source power
59... wide-band source power estimating means
[FIG. 13]
2... analysis means
3... spectrum analysis means
5... inverse filter
7... wide-band spectrum estimating means
8... vector quantizing means
11... inverse quantizing mean
14... wide-band source estimating means
17... synthesis filter
19... up-sampling means
18... band-pass filter
53... narrow-band power-inclusive spectrum code
54... source normalizing means
[FIG. 14]
2... analysis means
3... spectrum analysis means

5... inverse filter
7... wide-band spectrum estimating means
14... wide-band source estimating means
17... synthesis filter
18... band-pass filter
19... up-sampling means
61... post-filtering means
[FIG. 15]
Power
Frequency
[FIG. 16]
Power
Frequency
[FIG. 17]
7... wide-band spectrum estimating means
13... wide-band spectrum parameter
62... spectrum parameter converting means
63... degree reducing means
64... spectrum parameter inverse converting means
[FIG. 18]
7... wide-band spectrum estimating means
14... wide-band source estimating means
17... synthesis filter
18... band-pass filter
19... up-sampling means
101... narrow-band speech code
102... separating means
103... narrow-band spectrum code
104... narrow-band source code
105... wide-band spectrum decoding means
106... wide-band source decoding means
107... narrow-band spectrum decoding means
108... narrow-band source decoding means
109... narrow-band speech decoding means
[FIG. 19]

106... wide-band source decoding means
110... narrow-band pitch code
111... narrow-band power code
112... wide-band pitch decoding means
113... wide-band pitch period
114... wide-band power decoding means
115... wide-band power decoding means
[FIG. 20]
30... wide-band adaptive source estimating means
37... narrow-band long-period predictive analysis means
106... wide-band source decoding means
117... narrow-band adaptive source code
118... narrow-band excitation source code
119... wide-band adaptive source decoding means
120... wide-band excitation source decoding means
121... narrow-band adaptive source decoding means
122... narrow-band excitation sources decoding means
[FIG. 21]
42... wide-band long-period predictive residual estimating means
44... wide-band long-period prediction parameter estimating means
47... long-period synthesis filter
106... wide-band source decoding means
123... narrow-band long-period predictive code
124... wide-band long-period prediction parameter decoding means
125... narrow-band long-period prediction parameter decoding means
126... narrow-band long-period predictive residual code
127... wide-band long-period predictive residual decoding means
128... narrow-band long-period predictive residual decoding means
[FIG. 22]

7... wide-band spectrum estimating means

17... synthesis filter

18... band-pass filter

19... up-sampling means

102... separating means

105... wide-band spectrum decoding means

107... narrow-band spectrum decoding means

109... narrow-band speech decoding means

129... narrow-band power decoding means

130... wide-band normalized source decoding means